Big Qualicum River Salmon Development Project (Volume III)

F.J. Fraser, D.D. Bailey, and M.J. Wood

Resource Services Branch
Fisheries and Marine Service
Department of Fisheries and the Environment
1090 West Pender Street
Vancouver, B.C. V6E 2P1

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Fisheries and Marine Service
Technical Report No. 752

March 1978

BIG QUALICUM RIVER SALMON DEVELOPMENT PROJECT (VOL. III)

EXPERIMENTAL REARING OF CHUM SALMON JUVENILES (*ONCORHYNCHUS KETA*) IN FRESH WATER (1968 - 1970)

by

F. J. FRASER, D. D. BAILEY, and M. J. WOOD

Resources Services Branch
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Department of Fisheries and the Environment
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ABSTRACT

Fraser, F.J., D.D. Bailey, and M.J. Wood. 1978. Big Qualicum River Salmon Development Project (Vol. III): Experimental rearing of chum salmon juveniles (Oncorhynchus keta) in fresh water (1968 - 70). Fish. Mar. Serv., Tech. Rep. 752, Vancouver, B.C., 22p.

During the spring of 1968, 1969 and 1970 chum juveniles from the Big Qualicum River system were captured and reared under semi-natural conditions for periods ranging from 38 to 54 days. Fry were fed Oregon Moist Pellet diet. A total of 3.9 million juveniles were returned to the system, averaging 2.10 g (six times heavier than normal migrant fry). Growth in weight ranged from 2.99 to 3.88%/day, wet weight food conversions from 1.87 to 2.99, and rearing mortalities from 14.9% to 48.9%. Fin-clips and oxytetracycline were used to mark reared groups. Release dates varied from June 5 to July 4.

Migrant-to-adult survival for the 1968 brood was lower than wild survival (0.53% versus 0.65%) but survival for the 1969 brood was higher (0.94% versus 0.69%). Delay in juvenile release, relative to maximum local marine plankton abundance, is considered responsible for relatively low fingerling-to-adult survivals of reared groups.

KEY WORDS: chum salmon, reared, release size, predation, osmotic stress.

RÉSUMÉ

Fraser, F.J., D.D. Bailey, and M.J. Wood. 1978. Big Qualicum River Salmon Development Project (Vol. III): Experimental rearing of chum salmon juveniles (Oncorhynchus keta) in fresh water (1968 - 70). Fish. Mar. Serv., Tech. Rep. 752, Vancouver, B.C., 22p.

Au cours du printemps de 1968, de 1969 et de 1970, de jeunes saumons *kéta* ont été capturés dans le grand bassin de la rivière Qualicum pour être élevés dans un milieu semi-naturel durant des periodes allant de 38 à 54 jours. Les alevins ont été nourris avec des 'boulettes humides' Orégon. Au total, 3,9 millions de jeunes ont été renvoyés dans le bassin. Ils pesaient en moyenne 2,10 g, soit six fois plus que la normale pour un alevin migrateur. Le gain de poids a varié entre 2,99 et 3,88% par jour, l'indice de transformation entre 1,87 et 2,99 et la mortalité en élevage, entre 14,9 et 48,9%. Les groupes de culture ont été marqués à la terrafungine ou étiquetés aux nageoires. Les remises en liberté se sont faites entre le 5 juin et le 4 juillet.

Le taux de survie de la migration jusqu'à l'âge adulte a, en 1968, été plus bas qu'en milieu naturel (0,53% comparativement à 0,65%), mais plus élevé toutefois en 1969 (0,94% contre 0,69%). La remise en liberté tardive des saumonneaux de culture et les variations dans l'abondance du plancton marin local sont considérés comme les causes de leur faible taux de survie jusqu'à l'âge adulte.

INTRODUCTION

The natural mortality of salmonids through most of their life history stages is extremely high. Both freshwater and marine environments are often hostile. Eggs incubating in streambed gravel normally experience mortalities ranging from 80 - 95% (McNeil, 1968). The surviving fry must then face an even more varied and hostile environment in which the expectation of surviving to maturity is often less than 1% (Manzer, 1966).

Among the many physical and biological parameters affecting the rate of survival, juvenile migrant size is considered one of the most important. Senn and Noble (1968) found that hatchery coho released at average weights of 18.2 and 27.0 g had respective survivals of 2.8 and 6.0 times greater than coho released at 13.0 g. Foerster (1954) noted a similar relationship with sockeye smolts and Royal (1972) with hatchery chinook (Fig. 1). Data from Washington State hatcheries (Mathews and Senn, 1975) and Hokkaido hatcheries (T. Kobayashi, unpublished manuscript) show that the relationship also holds for chum salmon (Fig. 2).

Length of freshwater residency is largely responsible for differences in migration size among species (Fig. 3). Chum and pink fry normally migrate seaward immediately following emergence from the streambed gravel, while chinook, coho and steelhead spend from 90 days to four years in fresh water. The variation in timing of downstream migration of salmon species in the Fraser River is illustrated in Figure 4.

Because of the small size of chum and pink fry at migration and the coincidence of their migration with that of coho smolts, predation in both fresh and salt water is considered to be very high. Hunter (1959) estimated that freshwater predation of migrating pink and chum fry by coho smolts and sculpins in Hooknose Creek averaged 45.4% (range 22.6 - 88.5%) of the emergent population. Parker (MS, 1968) hypothesized that predation by coho smolts on pink fry caused high pink mortalities (2 - 4%/day) during their first forty days of marine residence (55 - 77% total mortality) but that a growth differential in favour of the prey reduced this mortality to 0.4 - 0.8%/day during the remaining ocean residence. It is possible that coho smolts also prey upon chum fry whose migration timing and early growth is very similar to that of pink fry.

Chum juveniles have been reared successfully in North America, Japan and the U.S.S.R. for several years. The rearing of chum and other species began in the U.S. in 1962 (Kral, 1963) and Russians began to keep chum fry in freshwater ponds and lakes as early as 1950. Nearly all chum produced in Japan since 1965 have been reared for one month prior to release.

It is not necessarily unnatural for chum fry to voluntarily remain in freshwater after gravel emergence. Chum fry have been found to feed naturally in fresh water in the Paratunka (Synkova, 1951) and Amur (Levanidov and Levanidova, 1957) river systems of the U.S.S.R. and in the Ishikari river system of Hokkaido (Sano, 1966). In North America, Tyler and Bevan (1964) and Walker and Lister (1965) have reported the capture of chum fry which had reared in fresh water. Chum fry collected near the end of the 1975 downstream migration period in Inches Creek (Fraser River drainage) were as large as 55.0 mm and 1.12 g (D. Bailey, unpublished data), as opposed to 39.0 mm and 0.36 g, the normal migrant size. Data shown in Table 1 from the Cowichan River (Sparrow, 1968) and Big Qualicum River (unpublished data) are also indicative of freshwater feeding. Fry collected in the lower sections of the Cowichan River were much larger than fry collected upstream and length-weight sampling at Big Qualicum included fry up to 82 mm and 3.15 g in the last few days of the downstream migration period.

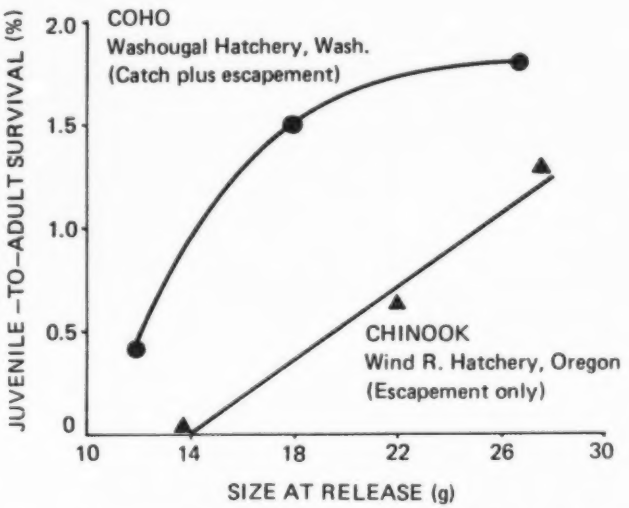


Figure 1. Juvenile-to-adult survival versus size at release for hatchery-reared chinook (Royal, 1972) and coho (Senn and Noble, 1968).

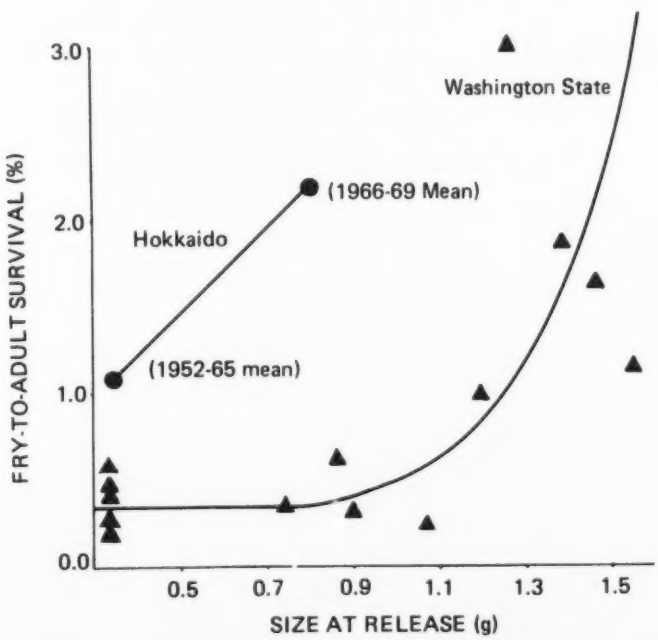


Figure 2. The relationship of fry-to-adult survival to size at release for hatchery-reared chum fry in Hokkaido (T. Kobayashi, unpublished manuscript) and Washington State (Mathews and Senn, 1975).

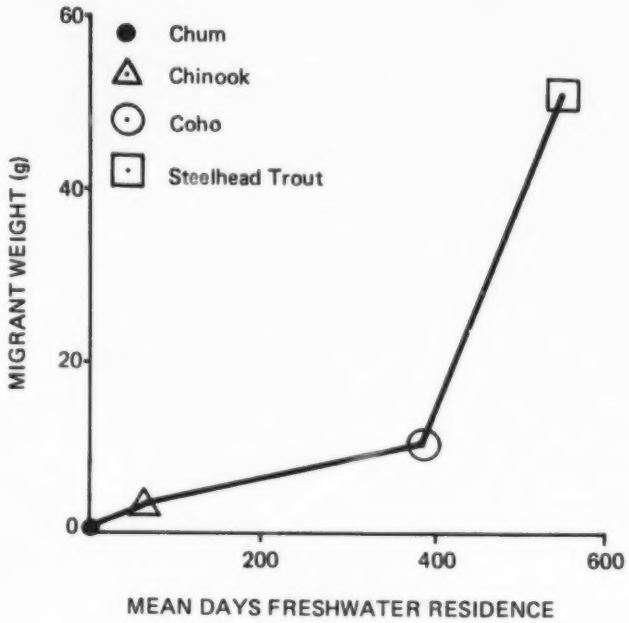


Figure 3. Migrant weight versus length of freshwater residence for four salmonid species. (Based on observations at Big Qualicum 1959-1972; Fraser et al, 1978b).

This natural freshwater rearing behavior coupled with the low mean fry-to-adult survival rate led to the design of a freshwater rearing experiment to test the hypothesis that size at migration and marine survival are directly related, and to determine if supplemental feeding is a viable enhancement technique. This report is an evaluation of a three year freshwater rearing program of Big Qualicum chum fry.

METHODS

REARING FACILITIES

In 1968, chum fry (1967 brood) were reared in a "Burrows" type (Burrows and Chenoweth, 1970) concrete rearing pond (15.2 m by 5.2 m by 1.1 m) at the Big Qualicum Experimental Hatchery (Fig. 5). Pelleted food was distributed by two 23 kg capacity automatic feeders equipped with timing mechanisms to control the frequency and duration of feeding. One feeder was installed on each side of the pond.

In 1969 and 1970, chum fry (1968 and 1969 broods) were reared in an artificial earthen spawning channel (579 m by 5.5 m by 0.6 m, with a gradient of 1:1000), which was modified for fry rearing purposes in 1969 (Fig. 6). The channel bottom, covered with 5 - 10 cm diameter gravel, was deepened a further 30 - 60 cm in 1970 to give a total depth of 0.9 - 1.2 m. Water for the channel comes directly from the river via intake works and a settling pond. During the experiment, a nylon net barrier and screens were placed at both ends of the rearing area to prevent the escape of fry. Nets were also placed over the channel to minimize predation by birds (Fig. 7).

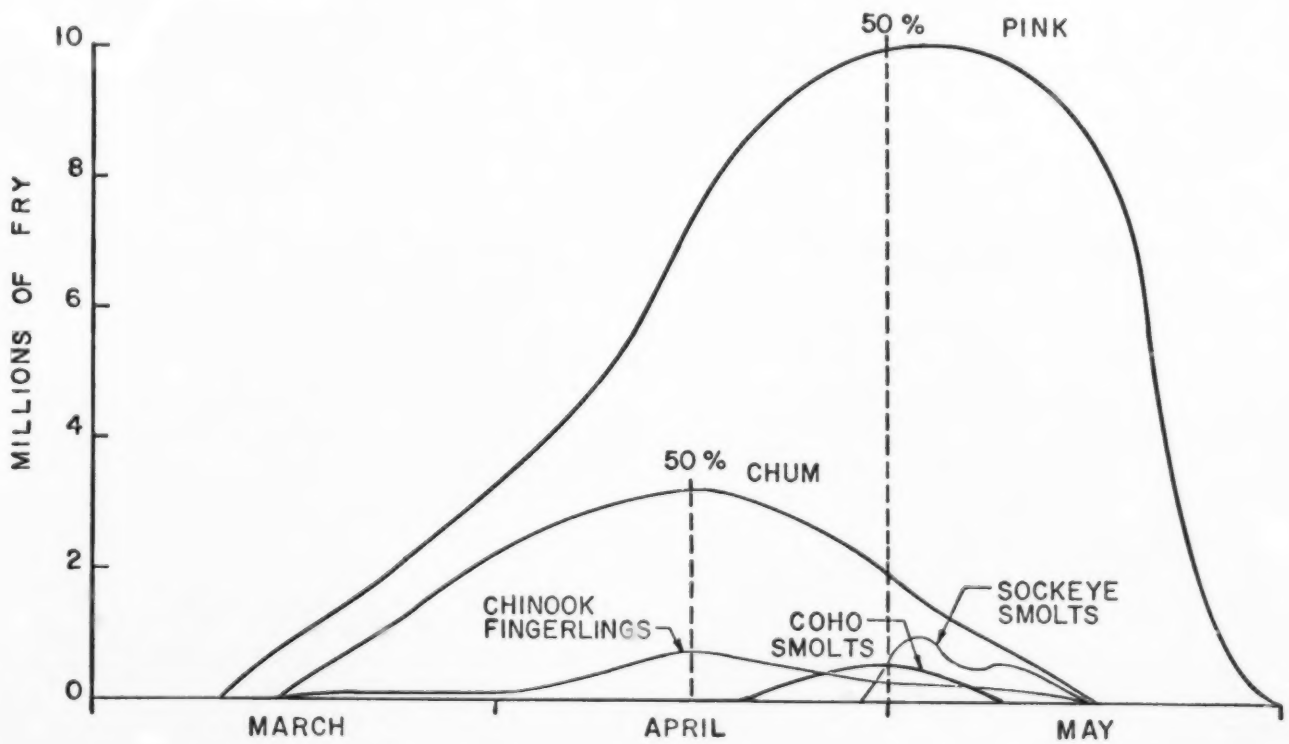


Figure 4. Juvenile migration timing curves of five Pacific salmon species in the Fraser River. (From Bailey and Fraser, 1978).

Table 1. Size of juvenile chum migrants from Cowichan[1] and Big Qualicum Rivers.

Sampling Site	Sampling Date	Length (mm) Mean Range	Weight (g) Mean Range
Cowichan R. (downstream)	1966 Apr. 24	55.3 (38–63)	1.40 (0.30–2.15)
	May 4	48.9 (39–66)	0.95 (0.40–2.35)
	May 12	53.6 (45–67)	1.26 (0.65–2.50)
(upstream)	May 4	38.7 (36–41)	0.38 (0.30–0.50)
Big Qualicum R.	1968 Apr. 24–May 25	39.6 (31–43)	0.35 (0.20–0.50)
	June 1	42.1 (Max. 68)	0.51 (Max. 1.81)
	1969 Apr. 21–June 22	38.8 (32–57)	0.35 (0.20–0.66)
	June 24–25	41.0 (58–62)	0.50 (1.83–1.93)
	1970 Apr. 26–May 27	38.9 (29–67)	0.35 (0.20–2.28)
	May 29–June 4	45.3 (33–82)	0.75 (0.21–3.15)

[1] Revised From Table II, Sparrow (1968).

In 1969, eight feeders under one master control timer were installed 15.2 m apart on the edges of the lower four sections of the channel. In 1970 two additional feeders were added and all ten feeders relocated on walkways in the centre of the channel (Figs. 6 and 7). The timing system was altered so that each feeder was controlled by an individual timer.

Four inclined plane traps (Fig. 8) were used to enumerate fingerlings released from the channel. Trap efficiency was determined by releasing known numbers of dye-marked fish above the traps and checking catches for mark recoveries.

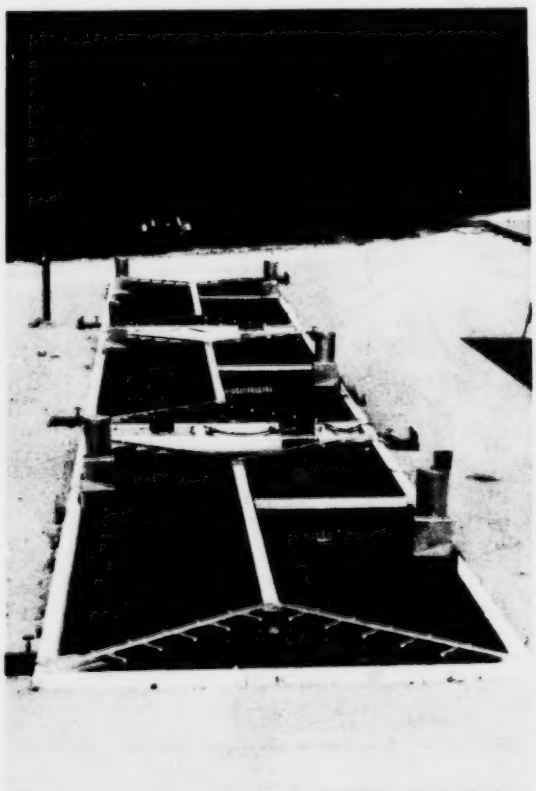


Figure 5. 'Burrows' type concrete rearing pond in which 1967 brood chum fry were reared at Big Qualicum.

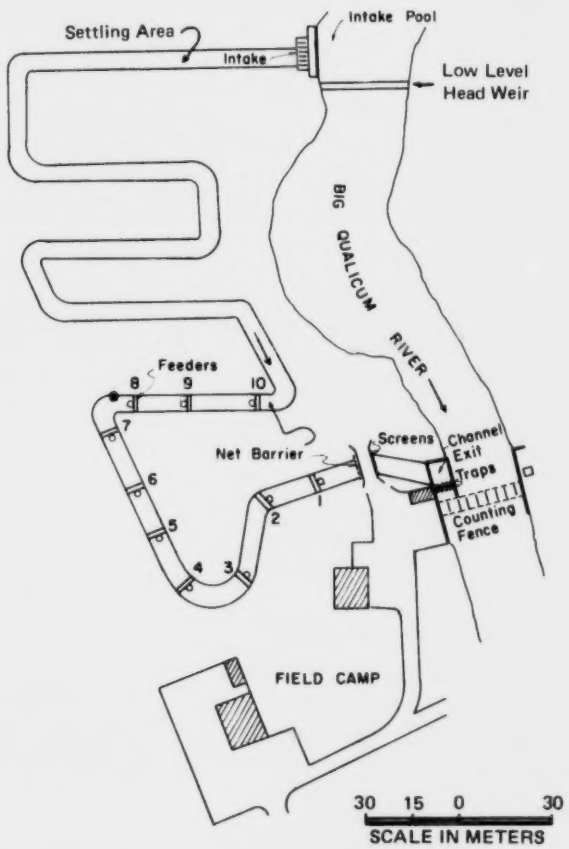


Figure 6. Big Qualicum River rearing channel

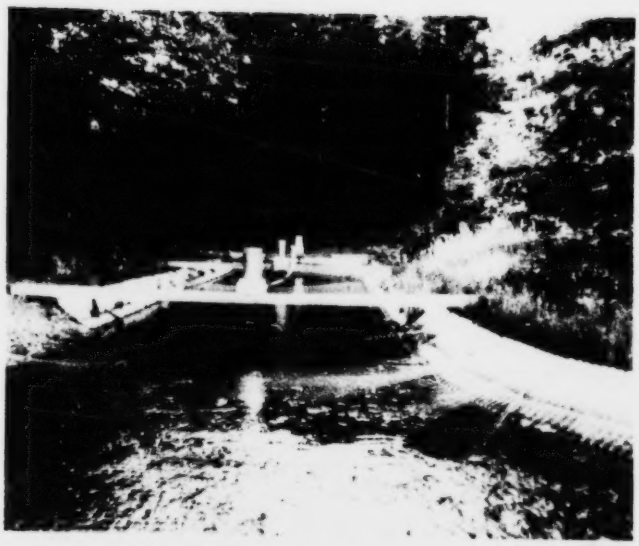


Figure 7. A portion of the Big Qualicum rearing channel showing three feeders and nets used to prevent predation.

Feeding rates were determined using daily food consumption and weekly weight data and were expressed as percent body weight per day. Food conversions were the increase in fish biomass divided by the wet weight of food distributed.

Water temperature was measured using a seven day recording thermograph. Mean daily temperature is a simple average of maximum and minimum temperatures.

Loading rate was determined for the 1967 brood reared in the "Burrows" pond and the 1969 brood in the channel by dividing the total estimated weight of fish present (mean weight per fish times total number of fish) by water flow. Loading rate was calculated from each length-weight sample. Loading rate was not calculated for the 1968 brood due to lack of flow data.

LENGTH-WEIGHT SAMPLING

Samples usually consisting of 150 fish were taken at five day intervals from the entire length of the channel. In 1968 and 1969 food was used to attract a group of fry and a sample was dip-netted. In 1970 a 6.0 m beach seine was used to capture a large sample, then a sub-sample was removed with a dip net. Fry were anaesthetized with a solution of 2-phenoxyethanol (3 - 4 mg/l), fork length measured to the nearest millimeter, weight determined to the nearest centigram and returned live.

Table 2. Food ration schedule for freshwater reared chum fry at Big Qualicum.

Weight of Fish (g)	Predicted Food Conversion Efficiency [1]		Feeding Level [2] (% body weight) per day	Food Size (mm)
	Burrow's Pond	Rearing Channel		
0.4–0.7	3:1	2:1	8.5–7.4	Mash–0.8
0.7–0.9	3:1	2:1	7.4–6.7	0.8–1.2
0.9–1.5	3:1	2:1	6.7–6.2	1.2–1.6
1.5–2.3	3:1	2:1	6.2–5.9	1.2–1.6

[1] Based on chinook and coho diet schedule.
[2] Adjusted for seasonal temperature change.

ORIGIN OF FRY

In 1968 fry were obtained from the river and chum spawning channel no. 2; in 1969 from the river, channel no. 2 and hatchery; in 1970 from the river and channel no. 2.

FOOD

Throughout the experiment, chum juveniles were fed Oregon Moist Pellet salmon diet in sizes ranging from a starter mash to 1.6 mm pellets. Feeding rates (Table 2) were based on chinook and coho diet schedules. The channel reared chum were allotted a smaller food ration than those in ponds because natural food sources such as terrestrial insects and drift organisms were available to the fish.

MORTALITY, FOOD CONSUMPTION, WATER TEMPERATURE AND LOADING RATE

Daily mortality was defined as the number of dead fish removed from the ponds during rearing and is referred to in this report as mortality index. Actual mortality, on the other hand, is the difference between the initial number of fry ponded and the number released. At time of release, a count-weight method was used to determine the number present.

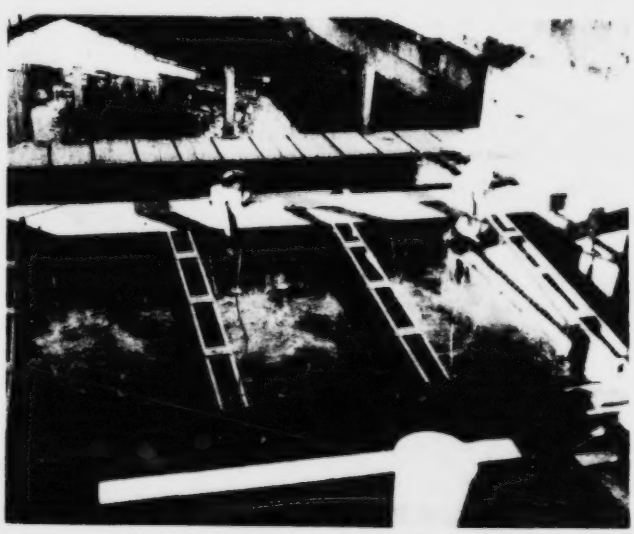


Figure 8. Inclined plane fish traps used to enumerate emigrants.

GROWTH RATE

Growth rates in length and weight were determined using the growth equation.

$$b = \frac{\ln Y - \ln a}{t_2 - t_1}$$

where b = the growth rate (%/day)
ln Y = the natural logarithm of final length or weight
ln a = the natural logarithm of initial length or weight
$t_2 - t_1$ = the rearing period (days)

Lengths and weights (with 95% confidence limits) were also plotted against time to illustrate growth during rearing.

FRY QUALITY DETERMINATION

Condition Coefficients

A coefficient of condition is one means of determining the general physiological condition of the fry. The usual mode of expression is:

$$Q = \frac{W(10^5)}{L^3}$$

where W is the weight in grams and L is the length in millimeters. The factor 10^5 brings the value of Q, the condition coefficient, near unity. This coefficient indicates seasonal changes in a fish's weight-length relation and can be used to compare groups of the same species and similar size ranges. According to Nikolsky (1963) this coefficient gives only a first approximation of physiological conditon but is valid for comparative analysis.

Weight-Length Relation

The slope (b) and Y intercept (a) of the weight (W) - length (L) relation $W = aL^b$ or $\ln W = a + b \ln L$ were determined from the growth data using the least squares fit method of regression analysis. The least squares fit curve, actual weights, and 95% confidence limits were plotted against length on a log-log basis.

MARKING

In 1968 a portion of the reared fry (1967 brood) were adipose fin-clipped prior to release. In 1969 a portion of the 1968 brood fry were adipose-anal fin-clipped while some others were adipose fin-clipped and fed tetracycline impregnated food just before release. In 1970 some of the 1969 brood fry were adipose-anal clipped before being placed in the channel and all fry were fed tetracycline impregnated food just before release. A portion of the normal migrants were also fin-clipped in order to distinguish between fry originating from the river and channel no. 2. The 1967 brood river migrants were marked adipose-right ventral (AdRV) and those from spawning channel no. 2 as adipose-left ventral (AdLV). The 1968 and 1969 brood river migrants were marked adipose-left ventral and those from channel no. 2 adipose-right ventral.

The tetracycline series of antibiotics localizes in areas of bone proliferation and under ultraviolet light is identified as a fluorescent yellow line. Weber and Ridgway (1967) give details of this marking technique.

Chum fry at Big Qualicum were fed a special mix of Oregon Moist Pellet containing oxytetracycline (OTC) (4.4 g active ingredient per kg of food), glucosamine and a low calcium content. In 1969 reared fry to be marked were placed in a 3.0 m diameter tub, fed normally for five days, starved for two days, fed OTC for six days, and fed normal food for three days prior to release. In 1970 reared fry were fed normally for 40 days, then fed OTC food for four days and finally fed normally for thirteen days prior to release.

Vertebrae from returning adults suspected of being marked with OTC were sliced into three cross sections with a scalpel and viewed under a microscope with darkfield ultraviolet illumination provided by a 200 watt mercury vapour lamp.

CHUM FRY MARINE STUDY

An independent study of chum juveniles was undertaken from April to August 1969 and 1970 in the marine area adjacent to the mouth of the Big Qualicum River (Fig. 9) to determine migration patterns and growth of juvenile chum (Fraser et al, 1978a). Lengths, weights and condition coefficients of marked wild and unmarked fry were compared with those of marked freshwater reared chum.

ADULT RETURNS

Fin-clipped adults were obtained from live-sampling at the Big Qualicum River fence and cannery surveys of commercially caught chum. Adult returns were calculated, based on marked fish from the river, channel no. 2 and freshwater rearing. Only adipose-anal marks were used in determining survival of freshwater reared chums because returns of tetracycline and adipose marked adults were too low to obtain statistically reliable estimates.

Orbital-hypural lengths and age composition (from scale analysis) were determined from samples of marked and unmarked fish. A two-tailed Student t-test was performed on orbital-hypural length data to determine if there was any statistical difference in size among the groups of marked and unmarked fish.

RESULTS

The essential data from rearing including rearing period, water temperature, loading rate, mortality, marking, growth rate, food consumption and food conversions are presented in Table 3.

REARING MORTALITY

Actual mortality during rearing totalled 14.9% for the 1967 brood, 25.0% for the 1968 brood and 49.8% for the 1969 brood. Mortalities calculated from the dead fish recovered in the 1968 and 1969 broods only totalled 16.3% and 19.5% respectively, making the differences between fish loss and dead recovered 8.7% and 30.3% respectively.

Mortality indices for each brood are graphed in Figure 10. In 1969 and 1970 mortality peaks occurred between 20 and 30 days after fry were ponded and, for all years, shortly before release (June 5 - 17).

In 1969 and 1970, the first mortalities were mostly inferior fry which, due to factors such as disease, physical defects, and competition, did not feed adequately and subsequently died. In the last two to three weeks (Day 40 to 60) of rearing in 1969

40 - 45 mm pinheads and 50 - 60 mm fingerlings were the main mortalities. Some had gill and tail fungus (*Saprolegnia sp.*) while others appeared healthy. During the last month (Day 24 to 54) of rearing in 1970, there was a high incidence of gill and tail fungus and mortality increased sharply. No fish were checked for other sources of disease, so it is not known whether the fungus was a primary or secondary infection.

GROWTH RATE

Graphs showing growth in length and weight for the three brood years are presented in Figure 11. Initial lags in growth were apparent for 1968 and 1969 broods. Sampling was insufficient to determine this for the 1967 brood. Otherwise, growth appeared to follow an exponential curve each year.

Overall growth rates given in Table 3 were calculated using initial and final mean lengths and weights. Mean growth rates and 95% confidence limits are graphed in Figure 12 along with some comparative data for chum rearing in salt water (Vanstone et al, 1970) and brackish water(Fedorenko et al, 1978). Growth in length increased from 0.77% to 0.94% to 1.03% over the three years and growth in weight from 2.99% to 3.38% to 3.88%. Differences were only significant (95% confidence) between 1967 and 1969 broods. Mean growth in fresh water was lower than in salt water but very similar to that for the natural population rearing in brackish water.

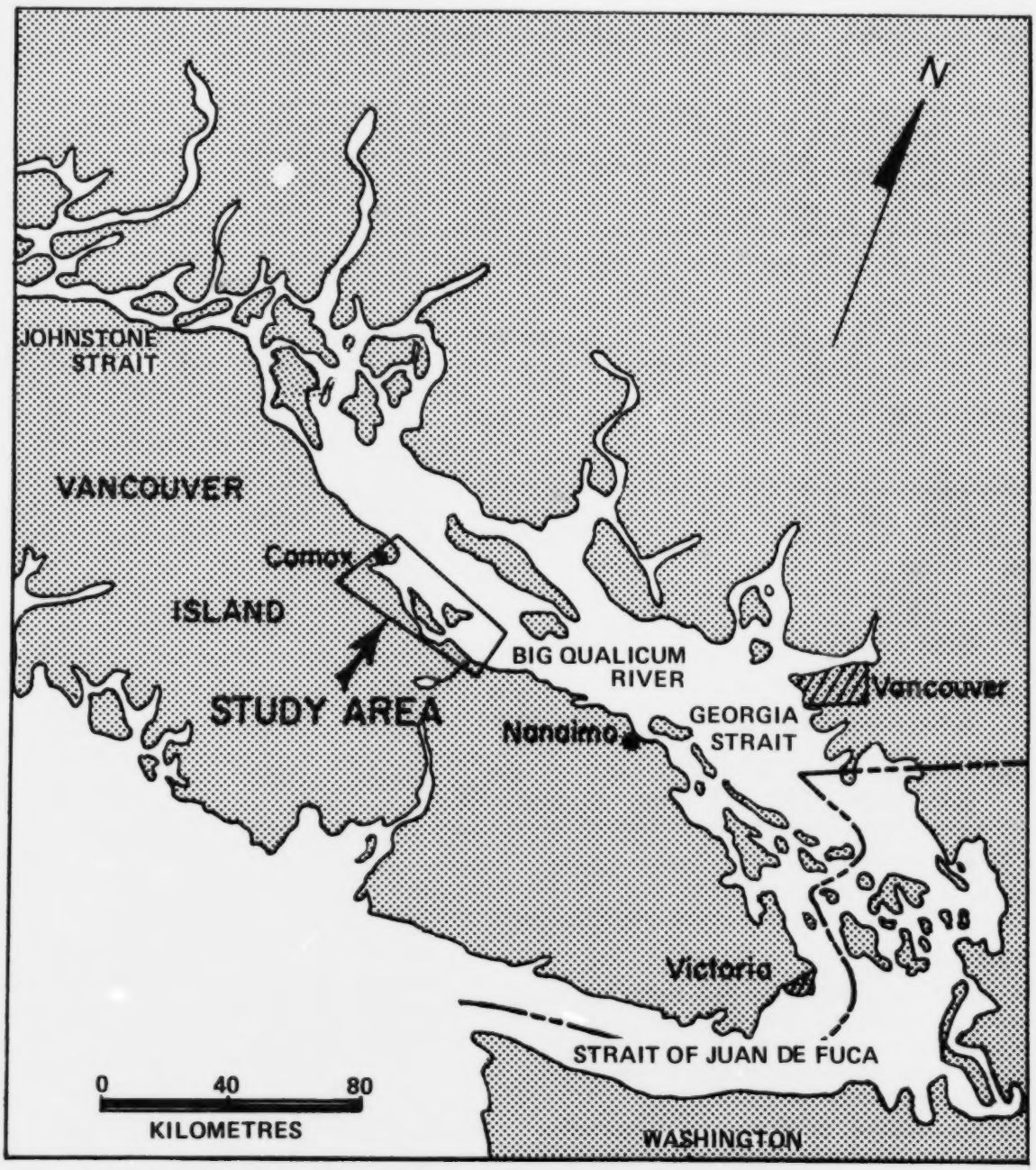


Figure 9. Map showing location of the Big Qualicum marine study area.

Table 3. Results of freshwater rearing of 1967, 1968 and 1969 brood chum juveniles at Big Qualicum including rearing period, water temperature, loading rate, mortality, marking, growth rate, food consumption, and food to fish conversion rates.

Brood Year	Mean Date Ponded	Mean Date Released	Mean Days Reared	Number of Juveniles Ponded	Number of Juveniles Released	Percent Mortality	No. Marked at Release	Mark Type	Percent Marked
1967	Apr. 28/68	June 5	38	205,100	176,300	14.9	17,400	Ad	9.87
1968	May 15/69	July 4	50	2,784,000	2,088,000	25.0	113,400 74,200	Ad–An Ad–OTC [2]	5.43 3.56 8.99
1969	Apr. 26/70	June 19	54	3,190,000	1,601,000	49.8	73,100 1,528,000	Ad–An–OTC OTC	4.57 95.43 100.0

Brood Year	Size of Marked Juveniles (g)	Water Temp [1] °C Mean (Range)	Loading Rate (Kg/l/min) Mean (Range)	Mean Length of Juveniles (mm) [3] In	Mean Length of Juveniles (mm) [3] Out	Mean Weight of Juveniles (g) [3] In	Mean Weight of Juveniles (g) [3] Out
1967	1.35	11.2 (8.8–14.2)	0.162 (0.126–0.199)	38.85 ±0.16	51.55 ±1.47	0.36 ± 0.014	1.12 ± 0.108
1968	1.73 1.25	9.7 (7.7–11.4)	Not Measured	38.63 ±0.99	61.93 ±3.43	0.35 ± 0.0064	1.90 ± 0.307
1969	2.92 2.93	11.8 (7.9–15.7)	0.15 (0.06–0.28)	39.51 ±0.17	68.77 ±4.22	0.36 ± 0.0057	2.93 ± 0.538

Brood Year	Condition Coefficient [3] In	Condition Coefficient [3] Out	Growth Rate (%/day) [3] Length	Growth Rate (%/day) [3] Weight	Food Fed (kg wet weight)	Biomass Increase (kg wet weight)	Food Conversion [4] (wet)	Feeding Rate (% body weight per day)
1967	0.614 (0.583–0.646)	0.819 (0.679–0.978)	0.77 (0.66–0.83)	2.99 (2.62–3.33)	341	127	2.69(2.41)	7.8
1968	0.607 (0.547–0.675)	0.800 (0.569–1.104)	0.94 (0.78–1.10)	3.38 (2.97–3.74)	5,590	2,992	1.87(1.60)	5.6
1969	0.588 (0.571–0.606)	0.901 (0.615–1.29)	1.03 (0.91–1.15)	3.88 (3.45–4.25)	10,583	3,543	2.99(1.91)	7.5

[1] Mean and range of daily mean temperatures
[2] OTC – oxytetracycline
[3] Ranges represent 95% confidence limits
[4] Numbers in brackets are adjusted for the weight gain of mortalities

FOOD CONSUMPTION

Fry fed aggressively at the start of each feeding but this behavior usually diminished before food distribution terminated. Low water velocity in the channel resulted in excess food settling to the bottom before it could be carried to downstream fry. Once out of suspension, food was rarely utilized.

The 1967 brood received 7.2% less food than the food ration schedule required, whereas 1968 and 1969 broods were fed more than the adjusted ration (11.8% and 37.0% respectively). Feeding rates ranged from 5.6 to 7.8% body weight/day, with the lowest in 1969. However, based on the above visual observations during feeding, it is possible that much of the excess food distributed in the channel was wasted.

FOOD-TO-FISH CONVERSION RATES

Food-to-fish conversion rates in Table 3 were calculated both excluding and including the weight gain of mortalities. Daily mortality and weekly length-weight data were used to obtain the latter. Both calculations are valuable – the first method

gives an indication of the actual success of rearing whereas the second measures the total amount of food that was converted to fish biomass. Only in 1970, when mortalities were highest, were the two substantially different.

Food-to-fish conversion rates calculated from wet weights, ranged from 1.87 to 2.99 excluding the weight gain of mortalities and from 1.60 to 2.41 including mortalities. The lowest conversion rate occurred in 1969, coinciding with the lowest feeding rate.

WATER TEMPERATURES, LOADING DENSITIES AND DISSOLVED OXYGEN

Water temperatures throughout rearing are plotted in Figure 13. Daily temperature means ranged from 7.7°C to 15.7°C during the three years of rearing with maximum temperatures reaching 17.8°C in June, 1970. Overall mean rearing temperatures were 11.2°C (1967 brood), 9.7°C (1968 brood) and 11.8°C (1969 brood).

The mean loading density and the range of weekly means for the 1967 brood chum reared in the Burrows pond are included in Table 3. Loading densities remained below 0.20 kg/l/min inflow, within the maximum loading density recommended by Burrows and Chenoweth (1970) for similar sized fry in Burrows ponds. By comparison, loading densities of chinook juveniles reared to 5.0 g in Burrows ponds at Big Qualicum averaged 0.25 kg/l/min and ranged from 0.14 to 0.43 kg/l/min. An overall loading density of 0.15 kg/l/min (range 0.06 - 0.28) was estimated for the rearing channel in 1970 with an average flow of 0.270 m^3/sec.

Dissolved oxygen was measured at both upstream and downstream ends of the channel in 1970 (Table 4). Levels ranged from 80 to 100% saturation upstream and from 69 to 86% downstream. The mean difference between the two ends was 15%.

FRY QUALITY DETERMINATION

Condition coefficients (Q) calculated from lengths and weights sampled during rearing and wild migration are presented in Table 5. Also included are condition coefficients of wild juveniles sampled in the Big Qualicum marine area. These were consistently higher than those for freshwater reared fry sampled during corresponding periods. There was an overall increase in Q throughout rearing, as depicted in Figure 14, and condition coefficients of reared fry at release were from 26 to 34% higher than those of the wild migrants. Changes in Q occurred in a step-like, rather than continuous pattern. There was no noticeable difference in Q, nor in its pattern of change, between chum fry reared in fresh water and those reared in seawater.

Results of the weight-length least squares fit regression analysis are presented in Table 6 and graphed in Figure 15. Values of "b" (slope) were 3.85 (1967 brood), 3.82 (1968 brood) and 3.57 (1969 brood), a higher value indicating better quality fry.

CHUM FRY MARINE STUDY

A map of the study area showing locations where marked chum juveniles were captured during 1969 and 1970 sampling is given in Figure 16. A comparison of lengths, weights, and condition coefficients of marked and unmarked fish sampled (Tables 7 and 8 shows that AdLV and AdRV clipped chum from Big Qualicum are similar in size to unmarked chum caught at the same time in the same area but AdAn chum are statistically shorter than both groups and tend to have lower weights and condition coefficients.

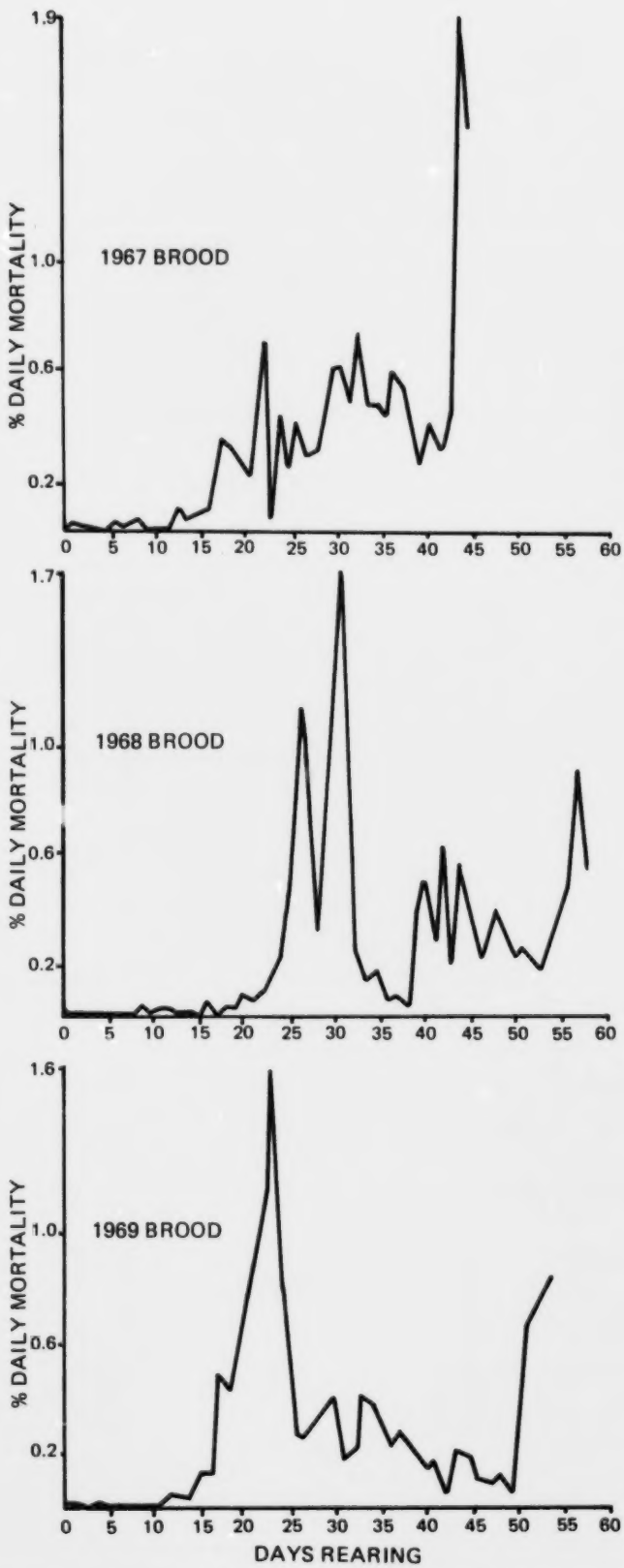


Figure 10. Mortality index of freshwater reared chum fry at Big Qualicum.

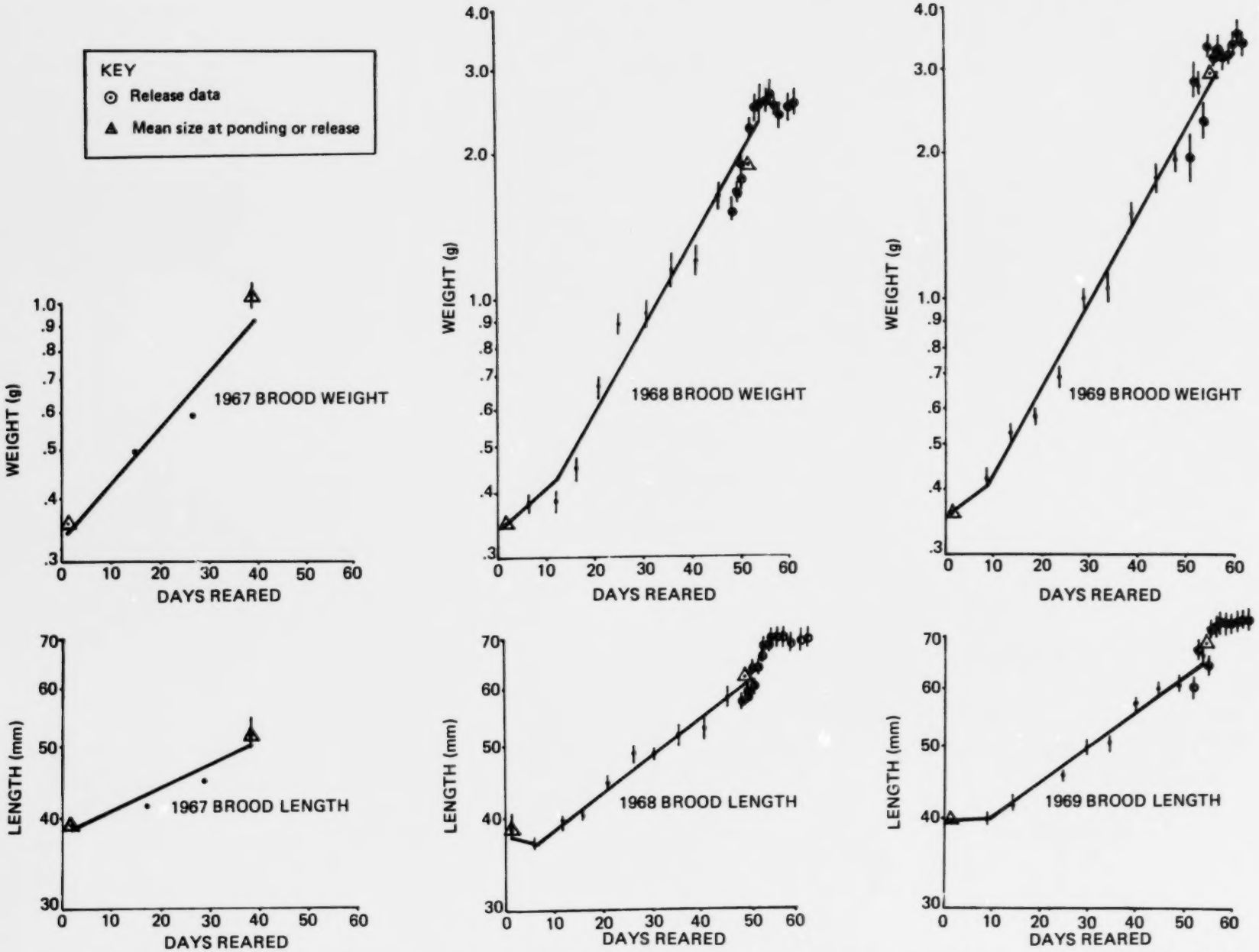


Figure 11. Growth in length and weight of juvenile chum reared at Big Qualicum. Only samples taken from the rearing population were used for establishing a least squares fit relation (solid line). Encircled points represent lengths and weights of daily samples of migrant or released fry. Vertical bars are 95% confidence limits on individual samples (where available).

Table 4. Dissolved oxygen levels in Big Qualicum rearing channel (1970).

Date	Time	Temp.(°C)	Dissolved Oxygen Upstream (ppm)	Upstream (% Saturation)	Downstream (ppm)	Downstream (% Saturation)
May 5	–	9.5	10.2	88	8.8	76
13	–	9.0	10.2	87	9.1	78
20	0900	10.5	9.1	80	8.3	74
20	1530	15.0	–	–	7.8	77
27	–	13.5	10.1	97	8.3	80
31	1430	16.0	9.4	95	7.2	72
June 10	–	12.0	10.4	95	7.4	69
15	–	12.8	10.6	100	9.2	86

Table 5. Condition coefficients of 1967, 1968 and 1969 brood freshwater reared chum fry at Big Qualicum and of 1969 brood wild chum fry sampled in the Big Qualicum marine area.

No. Days Reared	Condition Coefficient Q 1967 Brood	1968 Brood	1969 Brood	1969 Brood (Wild) Marine Sample 1970[2]
Downstream Migrants[1]	0.596	0.594	0.594	0.594
3	–	–	0.588[3]	0.790 (Apr. 13–30)
7	0.607[3]	–	–	
11	–	0.615[3]	0.674	
15	–	0.613	–	0.820 (May 1–15)
16	–	–	0.722	
20	0.715	–	–	
21	–	0.622	0.719	
25	–	0.678	–	
26	–	–	0.720	
30	–	0.761	–	1.16 (May 16–31)
31	–	–	0.800	
32	0.681	–	–	
35	–	0.791	–	
36	–	–	0.828	
40	–	0.822	–	
41	–	–	0.819	
43	0.819[4]	–	–	1.11 (June 1–15)
45	–	0.831	–	
46	–	–	0.835	
50	–	0.820	0.873	
55	–	0.831	0.943	
59	–	–	0.900[4]	1.14 (June 16–30)
63	–	0.802[4]	–	

[1] Calculated from weighted mean length and weight sampled over the entire migration
[2] Means for 15 - day sample periods
[3] Average Q of fry placed in rearing area
[4] Average Q of migrating fry, weighted for daily migration totals

Table 6. Slopes (b) and Y intercepts (a) of a least squares fit regression analysis of the weight-length relation ln W = a + b ln L, using growth data from freshwater rearing.

Brood Year	Number of Samples [1]	Least-square fit of weight on length ($W = aL^b$) a	S.E.	b	S.E.
1967	2	2.4	–	3.85	–
1968	9	2.1	0.7	3.82	0.14
1969	10	3.1	0.6	3.57	0.06

[1] Sample size = 150

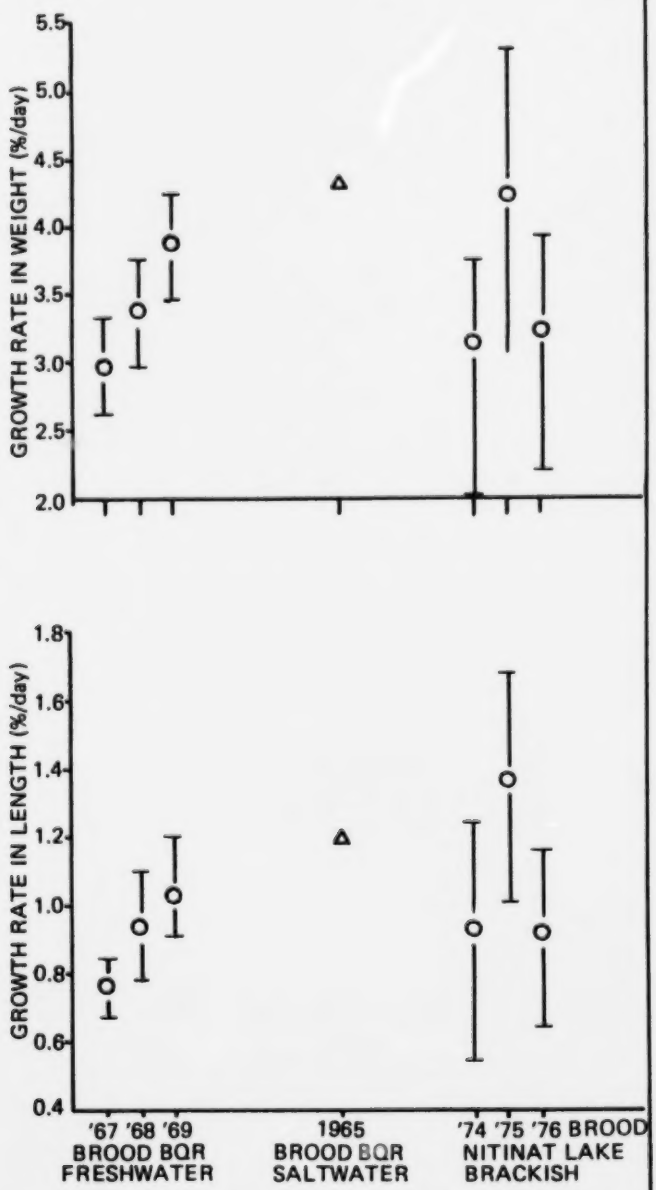


Figure 12. Growth rates during rearing of 1967-69 brood Big Qualicum chum fry. Also included are growth rates of 1965 brood Big Qualicum chum reared in salt water (Vanstone et al, 1970) and a natural rearing chum population from Nitinat Lake (Fedorenko et al, 1978). Vertical bars are 95% confidence limits (where available).

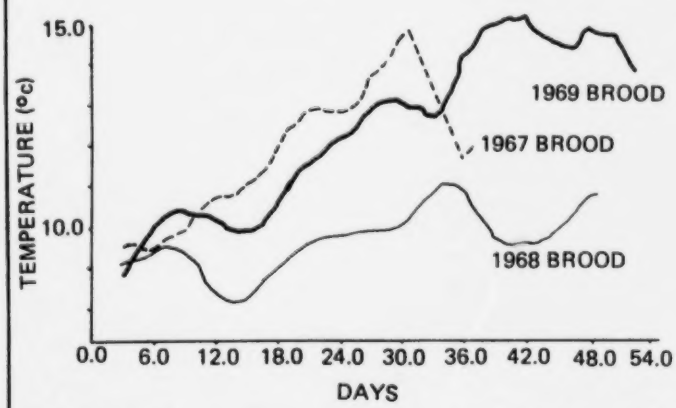


Figure 13. Water temperatures during rearing of 1967-69 brood Big Qualicum chum juveniles (five-day means).

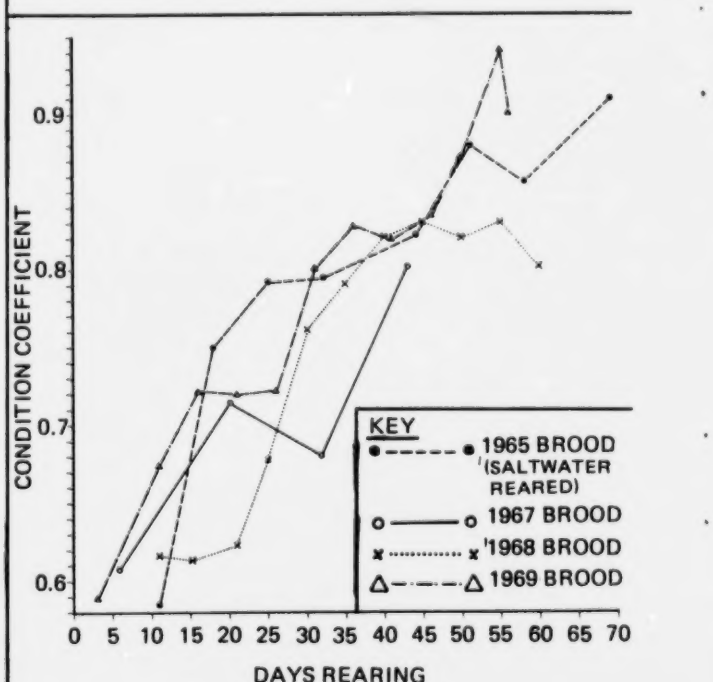


Figure 14. Condition coefficients for 1967, 1968 and 1969 brood chum juveniles reared in fresh water at Big Qualicum along with data from experimental saltwater rearing of 1965 brood Big Qualicum chum (Vanstone et al, 1970).

Table 7. Size and condition coefficients of marked and unmarked chum juveniles captured in the Big Qualicum marine area in 1970.

Date	Unmarked Chum [1] Sample Size	Length (mm)	Weight (g)	Condition Coefficient	AdLV [2] and AdRV [3] Marks Sample Size	Length (mm)	Weight (g)	Condition Coefficient	AdAn Marks Sample Size	Length (mm)	Weight (g)	Condition Coefficient
May 6	98	37.16	0.40	0.78	1	42.0	0.64	0.86	–	–	–	–
15	94	40.20	0.58	0.90	2	38.0	0.45	0.82	–	–	–	–
26	80	46.41	0.96	0.96	1	48.0	1.04	0.94	–	–	–	–
27	87	51.00	1.47	1.11	1	45.0	0.93	1.02	–	–	–	–
June 15	34	72.29	4.31	1.14	4	76.5	5.21	1.16	–	–	–	–
16	21	72.81	4.25	1.10	1	68.0	3.47	1.10	–	–	–	–
17	86	73.41	4.33	1.10	4	72.3	4.22	1.12	1	58.0	1.86	0.95
18	27	71.22	3.75	1.04	1	69.0	3.44	1.05	4	66.7	2.84	0.95
19	104	76.63	5.00	1.11	7	74.1	4.55	1.12	1	59.0	1.84	0.90
July 20	30	111.97	15.26	1.09	1	103.0	11.95	1.09	–	–	–	–
22	48	102.25	11.06	1.03	2	99.0	9.64	0.99	2	86.5	6.61	1.02
Means												
June 17–19	217	74.68	4.58	1.10	12	73.1	4.34	1.11	6	64.0	2.51	0.96
July 20–22	78	105.99	12.67	1.07	3	100.3	10.41	1.03	2	86.5	6.61	1.02

[1] Only includes unmarked chum found in samples containing marked chum.
[2] AdLV – river fry
[3] AdRV – channel no. 2 fry
[4] AdAn – reared fry

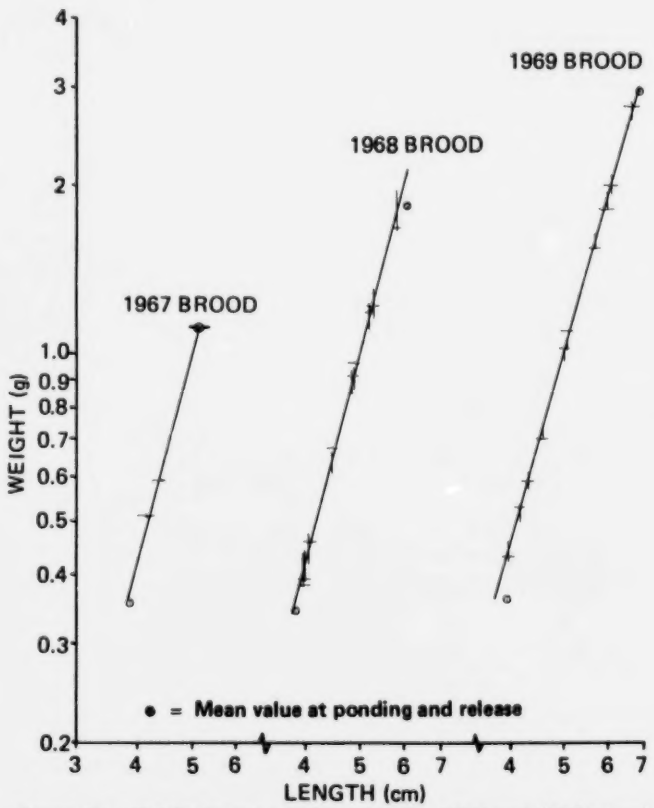


Figure 15. Weight-length relation of 1967, 1968 and 1969 brood chum fry reared at Big Qualicum. Vertical and horizontal bars are 95% confidence limits on individual samples.

Table 8. Results of t-tests comparing the fork lengths of marked and unmarked 1969 brood chum juveniles captured in the Big Qualicum marine area in 1970.

Sampling Date	"t" - value Unmarked vs AdAn	AdLV & AdRV vs AdAn	Unmarked vs AdLV & AdRV
June 17-19	2.98*	3.10*	0.62^{NS}
July 20-22	4.02*	6.34*	0.92^{NS}

* Significant at 0.05 level
NS Not significant at 0.05 level

ADULT RETURNS

Fry-to-Adult Survival

Estimated adult returns of reared, river, and channel no. 2 chum are presented in Table 9 and Appendix 1.

Because the mortality associated with the adipose-anal fin-clip has been found to be greater than that associated with adipose-ventral clips (Nicola and Cordone, 1973; Cope and Slater, 1957), an estimate of AdAn mortality for Big Qualicum chum, based on a curve relating adipose-anal to adipose-ventral mark mortality, has been made (Fraser et al, 1978b). Using a calculated adipose-ventral mortality of 5%, an AdAn mortality of 20% was estimated and used for the calculation of total returns.

Table 9. Fry output, migrant weight, estimated adult return and fry-to-adult survival of 1967, 1968 and 1969 brood Big Qualicum River, channel no. 2 and reared chum.

Brood Year	Group	Fry Output ($\times 10^6$)	Mean Weight at Release	Total Return (Including Catch)	Survival (%)
1967	River (AdRV)	21.6	0.35	77,000	0.36
	Channel No. 2 (AdLV)	11.6	0.36	34,100	0.29
	Reared (Ad)	0.18	1.12	–[1]	–
	Total	33.4			
1968	River (AdLV)	34.3	0.35	199,000	0.58
	Channel No. 2 (AdRV)	15.3	0.35	110,000	0.72
	Reared (AdAn)	2.09	1.90	10,980	0.53
	Total	51.7			
1969	River (AdLV)	41.9	0.35	280,000	0.67
	Channel No. 2 (AdRV)	19.5	0.35	138,000	0.71
	Reared (AdAn)	1.60	2.93	15,100	0.94
	Total	63.00			

[1] Insufficient number of fingerlings marked to accurately determine adult returns.

Table 10. Percent age composition and rate of commercial exploitation of Big Qualicum chum returns for 1967, 1968 and 1969 broods.

Brood Year	Group	Percent Age Composition			Percent Commercial Exploitation
		3	4	5	
1967	River	15.6	76.2	8.2	14.1
	Channel No. 2	14.4	72.5	13.1	12.7
	Reared	–	–	–	–
1968	River	5.75	65.8	28.4	59.0
	Channel No. 2	7.24	66.5	26.2	67.3
	Reared	3.00	85.8	11.2	61.3
1969	River	4.83	86.0	9.2	55.3
	Channel No. 2	4.86	80.0	15.1	61.1
	Reared	0	84.3	15.7	74.8

Mean weights at migration for the various groups of chum are given in Table 9. Normal migrants were consistently around 0.35 g whereas the size of reared groups at release increased each year from 1.12 to 2.93 g. Fry-to-adult survival is plotted against migrant weight in Figure 17. Although a positive relationship is suggested, the correlation is not significant.

Age Composition and Commercial Exploitation

The age composition and commercial exploitation for returning adult chums are given in Table 10. Age compositions for river and channel no. 2 fish were similar within each brood year but varied considerably between years. AdAn marked fish had a lower rate of return at age 3 than did river and channel fish. Commercial exploitation varied between groups with a particularly high rate for the 1969 brood reared group.

Size of Returning Adults

Four-year-old chums sampled at various sites were measured to determine if origin of the fish would affect size. Results presented in Table 11 and 12 show that AdAn marked chum are significantly shorter than normal migrants, with the exception of the 1969 brood channel fish where the difference was not significant.

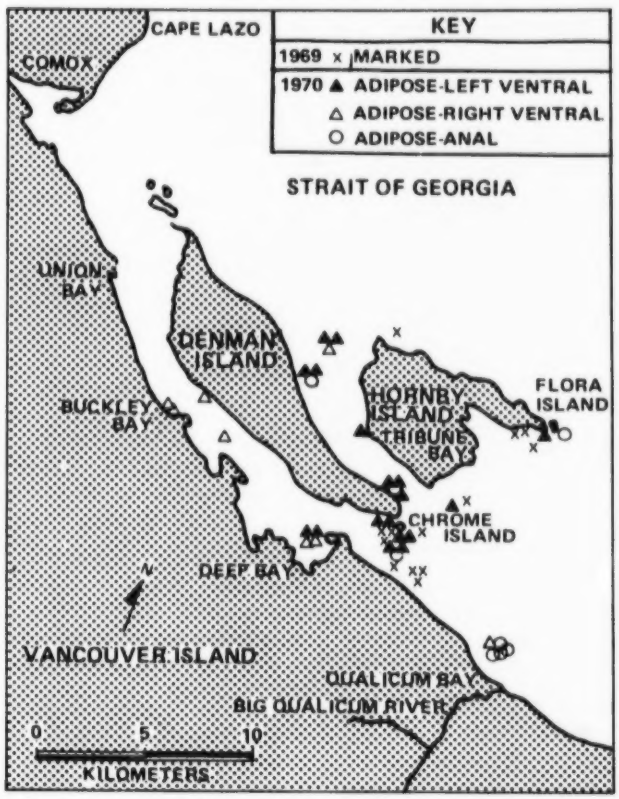


Figure 16. Big Qualicum marine area showing 1969 and 1970 capture locations of marked chum juveniles.

Routes of Migration

The majority of adult chums returning to Big Qualicum approach the river from the north via Johnstone Strait but some also return from the south via the Strait of Juan de Fuca (Fig. 9). An analysis of marked adults sampled in the commercial catches from the two areas (Table 13) has shown that the percentage of reared chum returning via the southern route is approximately five times greater than that of the normal migrants.

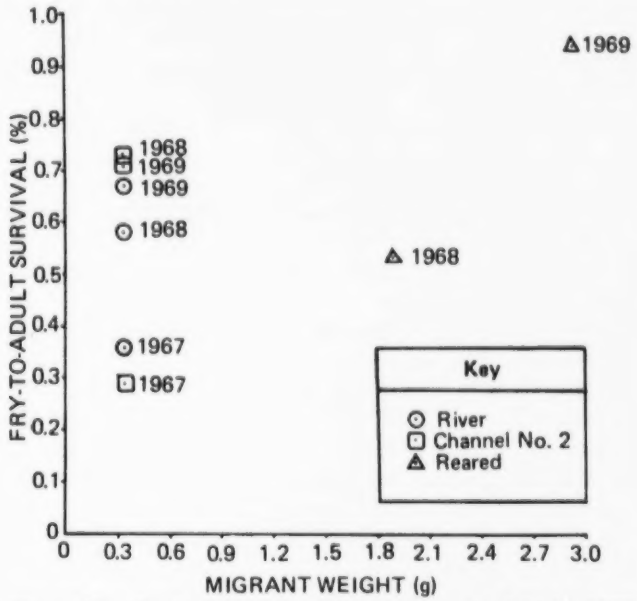


Figure 17. Fry-to-adult survival versus migrant weight for 1967-1969 brood river, channel No. 2 and freshwater reared chum.

Table 11. Orbital-hypural lengths of age four 1968 and 1969 brood freshwater reared (AdAn) chum adults, normal migrants (AdLV, AdRV) and unmarked adults.

Brood Year	Sampling Site	Reared (AdAn)			River (AdLV)			Channel 2 (AdRV)			Unmarked		
		Mean Length	n	S.D.	Mean Length	n	S.D.	Mean Length	n	S.D.	Mean Length	n	S.D.
1968	Canneries	570.2	41	28.2	579.0	1306	24.0	578.2	378	23.6		no data	
	Channel Dead	566.4	21	28.3	576.1	22	25.7	578.6	7	18.9	576.0	745	25.8
	River Dead	567.5	4	15.6	576.5	34	27.6	567.7	11	26.3	576.5	805	24.8
	River Live	569.3	15	28.4	586.5	356	24.8	586.6	74	19.4	585.0	796	25.2
	1968 Mean	568.9	81	27.4	580.5	1718	24.5	579.3	470	23.2	579.2	2,346	25.6
1969	Canneries	580.5	42	28.2	587.9	416	23.7	587.3	271	27.0		no data	
	Channel Dead	590.9	1	0.0	600.0	13	14.3	588.3	9	19.7	597.3	731	23.4
	River Dead	–	0	–	593.0	5	15.3	571.4	7	20.2	593.2	348	25.4
	River Live	592.5	6	13.0	601.8	111	27.1	587.7	52	23.6	599.9	538	23.9
	1969 Mean	582.2	49	27.0	591.1	545	24.2	587.1	339	26.3	597.3	1,617	24.0

Unmarked: from river, channel or freshwater rearing
Canneries: from commercial catches, sampled at canneries
Channel Dead: dead adults recovered from chum spawning channel no. 2
River Dead: dead adults recovered from river above main fence
River Live: escaping adults, trapped at main fence

Table 12. Results of a two-tailed t-test of significance comparing orbital-hypural lengths of 1968 and 1969 brood age four freshwater reared chum (AdAn), normal migrants (AdLV and AdRV) and unmarked adults.

Brood Year	Sampling Site	AdAn versus AdLV	AdRV	Unmarked
1968	Canneries	2.30*	2.04*	–
	Channel Dead	1.18	1.05	1.67
	River Dead	0.63	0.16	0.72
	River Live	2.62**	2.90**	2.39*
	1968 Mean	4.13**	3.62**	3.56**
1969	Canneries	1.89	1.51	–
	Channel Dead	0.67	0.08	0.31
	River Dead	–	–	–
	River Live	0.83	0.49	0.76
	1969 Mean	2.43*	1.22	4.32**

* Significant at 0.05 level
** Significant at 0.01 level or below.

Table 13. Ratio of reared (AdAn) to unreared (AdLV and AdRV) chum adults sampled in the commercial catches from Johnstone Strait and Strait of Juan de Fuca in 1972 and 1973.

Year	Mark Type	Number of Marks Caught Johnstone St.	Juan de Fuca	Percent of Marks in Juan de Fuca
1972	AdLV + AdRV	1,224	29	2.3 %
	AdAn	16	2	11.1 %
1973	AdLV + AdRV	776	4	0.51%
	AdAn	39	1	2.50%

DISCUSSION

MORTALITY

Chum rearing mortality at Big Qualicum was high relative to other chum rearing results, however, approximately 50% of the mortalities each year occurred after 30 days, the normal chum rearing period at other hatcheries. Estimates of mortality during the first 30 days are 6.8%, 11.5% and 25.4% for the 1967, 1968 and 1969 broods respectively. By comparison, mortalities of chum fry reared in ponds at Hoodsport hatchery in Washington State have ranged from 5 - 10% (H. Senn, pers. comm.). Chum fry reared at Thornton Creek Hatchery on the west coast of Vancouver Island (1976 brood) had less than 5% mortality during 35 days of rearing, reaching a size of over 1.0 g by April 6 (K. Peterson, pers. comm.). Mortality of chum fry reared in freshwater in 1.2 m diameter ponds at Snettisham, Alaska totalled 3.4% over 60 days (H. Heinkel, pers. comm.).

Visible causes of mortality were disease and predation. Other less obvious factors could include high temperature stress and osmoregulatory problems associated with being held in fresh water after normal migration time (Houston, 1957).

The mortality peaks observed each year are likely due to two separate causes. The first peak, occurring between 20 and 30 days, may represent selection against inferior fry. The second, occuring towards the end of rearing, could be the result of stress and disease, brought about by delayed seaward migration.

Predation represents a major source of mortality in the channel and was the main reason for the large discrepancy between actual and recorded mortalities. The location of the channel away from buildings and human activity makes it more accessible to terrestrial and avian predators than are the more exposed rearing ponds.

Fungal disease could have resulted from high water temperatures, high concentrations of metabolic wastes, particularly in the lower end of the channel where fry congregated, and deterioration of unutilized food on the channel bottom.

Hoar (1958) noted that it is extremely difficult to retain pink and chum fry in fresh water for more than three months after normal migration time. The resulting increase in mortality is attributed to osmotic stresses caused by a change in the ability of the fish to regulate their water and salt balance. Baggerman

(1960), holding chum fry in fresh water, found that the fry preferred fresh water until early May when the preference shifted to salt water. The fish grew well until June, when mortality increased. By November, all fish had died.

Baggerman (1963) postulated that the change from freshwater to saltwater preference was controlled by increasing daylength in the spring which stimulates the activity of the endocrine system, principally the thyroid gland. Treatment of pink fry with thyroid inhibiting substances (thiourea, thiouracil and sodium thiocyanate) induced a freshwater preference in fry previously preferring salt water. The inclusion of these drugs in the diet of freshwater reared chum might reduce potential osmotic stress. Other possible solutions could be to start rearing earlier and shorten the rearing period, confine rearing to salt water or to have salt water available as a water supply.

GROWTH RATE

Growth rates of freshwater reared chum fry appear to be slightly lower than other figures available. For example, fry from the Nitinat River migrate and rear for 40 to 60 days in Nitinat Lake, a large brackish body of water on the west coast of Vancouver Island. Temperatures during the rearing period vary from 8° - 15°C and salinities from 22 - 30 parts per thousand below 5.0 m. Fry were sampled for length and weight in 1975, 1976 and 1977 and growth rates averaged 1.07% length/day and 3.51% weight/day over the three years (Fedorenko et al, 1978). Corresponding mean values at Big Qualicum were 0.91% length/day and 3.42 % weight/day.

Chum fry from Big Qualicum spawning channel no. 1 (1965 brood) were reared for 50 days in seawater pens at Deep Bay (Vanstone et al, 1970). They were fed once daily on an excess wet diet of beef liver, beef heart, canned salmon and pablum but also had access to natural food organisms drifting through the pen. Growth rates, averaging 1.2% length/day and 4.3% weight/day were also higher than those of freshwater reared chum.

In 1965 Soviet scientists reared 1.7 million chum fry for 37 days in a freshwater pond similar to the rearing channel at Big Qualicum (Edelsberg, 1970). The fry fed on natural benthos supplemented by walleye pollock eggs. The daily weight increase averaged 11.3 mg/fish/day as opposed to 23.8 mg/fish/day obtained at Big Qualicum. The type of food and smaller rations may account for the difference.

The above data suggest that growth in salt water is greater than in fresh water. The energy involved in maintaining thyroid hyperactivity in fresh water (Baggerman, 1960) could explain the slower growth.

Parameters considered the most influential on growth rates are temperature, feeding rate, fish size and loading rate. Other factors, however could exert considerable indirect influence on apparent growth rates.

Brett et al (1969) determined that temperature and food ration have a combined effect on growth rate. When fed excess ration, an optimum growth temperature exists (around 15°C for most salmon species) and this optimum decreases as food ration is decreased. The study also revealed that as fish size increases, growth rate decreases, resulting in a series of growth stanzas. This was not observed with Big Qualicum chum, either because the time period was not long enough or because of the overriding effect of other rearing parameters.

If growth rates of Big Qualicum chum are compared to temperature and feeding rate, no correlation is noted over the three years. Looking at the channel alone the lower temperature in 1969 (9.7°C) than in 1970 (11.8°C) could be responsible for the lower growth rate (13% lower). Growth of sockeye at 9.7°C and 11.8°C, fed on excess ration, were 1.8% and 2.2% weight/fry respectively, a difference of 18% (Brett et al, 1969). Since excess food in the channel was wasted, particularly in 1969 the calculated feeding rates would not represent the exact amount of food consumed and would therefore not necessarily be precisely correlated to growth rates.

Loading density may have an effect on growth rate. Burrows (1964) found that at 12.8°C, loading densities exceeding 0.60 kg/l/min inflow usually resulted in the dominant production of un-ionized ammonia instead of non-toxic urea and that when unionized ammonia became the dominant nitrogenous waste product, growth rate, physical stamina and disease resistance were impaired. Loading densities measured at Big Qualicum were below this recommended maximum, but crowding in the lower end of the channel and around feeders may have increased localized densities above the recommended maximum.

Other factors which may have influenced growth rates include rearing method (pond versus channel), mean daylength, and mortality. The latter, although not influencing the actual growth of any given fish may affect the apparent growth rate of the group if mortality selection of either large or small fish is taking place. The positive correlation of growth rate to mortality at Big Qualicum suggests that the smaller fish experienced greater losses.

Increases in length and weight followed slightly different patterns each year but were treated as simple exponential functions with the exception of an initial growth lag which appeared to be consistent from year to year. Deviations from the exponential curve could be due to varying conditions during rearing or to inadequate sampling. The initial growth lag is likely the result of the physiological shock of adjusting to aborted migration and learning to feed on prepared food.

FOOD CONSUMPTION AND FOOD-TO-FISH CONVERSIONS

Wasted food was the main reason for relatively high food conversions (mean 2.48:1). Estimated food conversions for Hoodsport hatchery (Washington State) are from 1.0 - 1.2:1 using Oregon Moist Pellet (R. Foster, pers. comm.). Values in Hokkaido hatcheries are estimated at 1.5:1, using a dry diet (7.0 - 10.0% moisture). This would be equivalent to a value of 1.96:1 for OMP with 30% moisture content. The low food-to fish conversion rate for the 1968 brood corresponded to a low feeding rate. This low feeding rate indicates that feeding rates need not exceed this amount (5.6% body weight per day) in the channel.

Unknown daily rates of mortality made estimates of food requirements difficult. With a better knowledge of the fish biomass present, and natural food availability, feeding rates could be adjusted to minimize food waste. Stomach sampling could yield some useful information on the extent of natural food utilization.

Food wastage might also be reduced by feeding more frequently but for shorter duration and by increasing the flows in the channel to facilitate better food particle suspension.

FRY QUALITY

Fluctuations in condition coefficients throughout rearing may represent true variations in growth in length and weight or may merely reflect sampling variability.

Condition coefficients for 1969 brood wild fry sampled in the marine area were from 15 - 35% higher than for those reared in fresh water, suggesting that rearing in salt water produces better quality fry.

Condition coefficients upon entering the marine environment were higher for reared fish than normal migrants. This is because, as the fish grew, the weight increased at a rate greater than the cube of length. The mean condition coefficient for the 1968 brood at release was lower than that for the 1967 brood, even though the average size was larger. This could be due to the lower temperature in 1969, the different rearing locations, or stress associated with being held so late (mean release date July 4).

Condition coefficient at release may have some influence on future survival, particularly if there is a food shortage (Poliakov, 1950; Kirpichnikov, 1958; Burrows, 1969) however, time of release and size at release probably have as great an influence on early marine survival.

The lower slope value of the 1969 brood weight-length relation indicates that growth in weight relative to growth in length was less than the other broods, however, since final condition coefficients were highest for the 1969 brood, this difference was probably insignificant. Slopes for the Big Qualicum chum fry reared in seawater (Vanstone et al, 1970) were 3.32 and 3.24 for river and channel no. 1 fry respectively, somewhat lower than values for freshwater reared fry. A longer holding period and differences in diet could account for these lower values.

Marking Problems

Use of both adipose and adipose-anal fin-clips have been found undesirable. The adipose clip was found unreliable because too few juveniles were marked. Adults so marked could have resulted from two additional sources: naturally missing adipose from unmarked fish (an estimated 0.05% of the population) or regenerated ventral fins from AdLV and AdRV clips. Since the numbers of wild fry, both marked and unmarked, were so large, the marking interference could have been high enough to account for all of the adipose only returns from the 1967 brood.

Adipose-anal clips should be avoided because of increased mortality associated with removal of the anal fin (Nicola and Cordone, 1973). This is probably due to the large wound and infections arising from its proximity to the anus. A mortality test was carried out on 1500 of the 1969 brood chum at Big Qualicum. Fry were marked (AdAn) and held for 20 days in a 1.8 m diameter tank previously disinfected with formalin. Although mortality was only 5.9% and no signs of fungus were noted, the chance of disease would probably be much higher in the channel where excess food and dead fry could act as disease sources and where fish were held longer and at higher temperatures and loading densities.

There are three alternative stock identification techniques available which offer advantages over fin-clipping; these are:

Coded Wire Nose-Tagging

This method, described by Bergman et al (1968) has been used recently on 45 - 48 mm chum fry with tag loss and marking mortality averaging 2 - 3% after one week. Advantages include minimal visible effects and a wide variety of codes. The main disadvantage is that the procedure is very slow (250 to 375 per hour as opposed to 500 - 600 fin-clips per hour), but a reduction in tag diameter is expected to both allow a faster rate of tagging, and the tagging of smaller fry (35 - 45 mm — K. Jefferts, pers. comm.).

Freshwater Growth Patterns on Scales

Scale characteristics of Big Qualicum chum adults vary between normal migrants and freshwater reared individuals (identified also by adipose-anal clips). In reared fish, the original 5 - 6 circuli formed during freshwater residence were more widely spaced than were subsequent saltwater circuli. A check was easily identified in the transition zone at 6 - 7 circuli (C. Pope, pers. comm.). In normal migrants no such check is present. Figure 18 shows the two types of scales. Examination of scales of returning adults could provide a means of assessing adult returns without interfering with survivals, however, its reliability is not known and should initially be used in conjunction with fin-clipping.

Tetracycline Marking

The advantages of this technique are elimination of handling of fry and visible external marks.

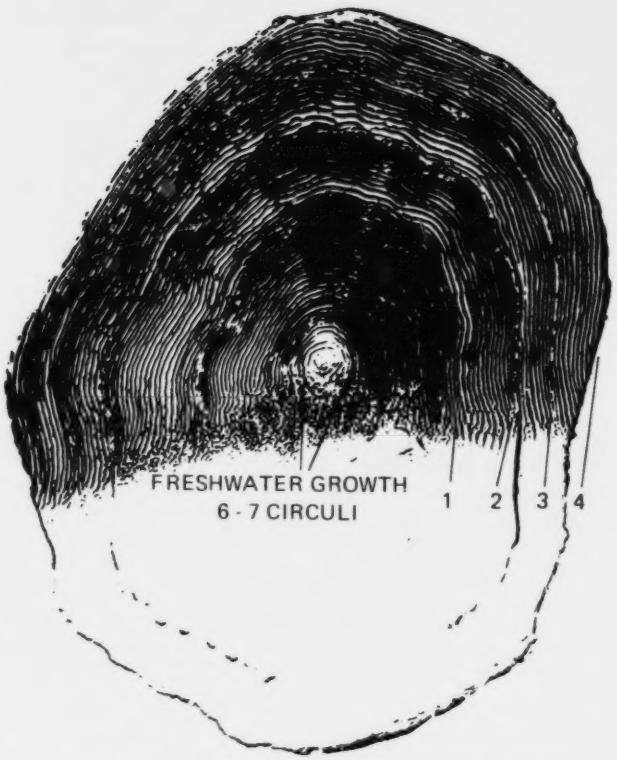
Sampling for tetracycline marks in 1968 and 1969 brood Big Qualicum chum was insufficient to properly evaluate this marking technique but some indication of its success was obtained. Of the 337 fish checked in 1972 and 1973, it was calculated (based on fin-clipped returns) that 32 should have been tetracycline positive, however, only two were faintly positive. These poor results indicate that fish were either too small at marking or were unable to receive an adequate dose due to some physiological factor.

Although chum juveniles as small as 2.06 g have been successfully marked with 2 g/kg oxytetracycline (Weber and Ridgway, 1967), it is possible that the optimum rearing period at Big Qualicum would result in the release of fish at a smaller size than this. If so, tetracycline marking would be impossible.

MARINE STUDY

Apart from a possible mark effect, the smaller size of adipose-anal marked juveniles in the Big Qualicum marine area compared to normal migrants could indicate that growth rates were lower for those held in freshwater. The higher growth rates of Big Qualicum chum held in saltwater pens (Vanstone et al, 1970) supports this.

It should be noted that the size of marked fish may be affected by stress imposed by removal of the adipose and anal fins, particularly the anal fin. Since mortality is increased due to the double clip, it is possible that growth is also reduced. If this is so, then the smaller size of AdAn individuals may not be representative of the entire reared population and no definite conclusions can be based on these data.



A) FRESHWATER REARED CHUM (1969 BROOD)

B) NORMALLY REARED CHUM (1969 BROOD)

Figure 18. Comparison of scales from normal and freshwater reared chum adults from Big Qualicum.

The normal migrants may have been larger due to the removal of the smaller fry by predators (Parker, 1971). The reared fry were protected from aquatic predators, therefore, the selection against smaller individuals was probably less intense during the critical period of small size.

ADULT RETURNS

Migrant-to-Adult Survival

Survival of reared fry was higher than that for normal migrants for the 1969 brood but slightly lower for the 1968 brood. Although the overall migrant-to-adult survival rate was higher for the reared group, fry loss during rearing caused a decrease in potential adult production. It is also evident that size is not the only factor affecting marine survival.

Another factor that is probably of major importance is timc of release. Figure 19 shows the distribution of the wild migrations of 1967, 1968 and 1969 brood chum at Big Qualicum. Fry

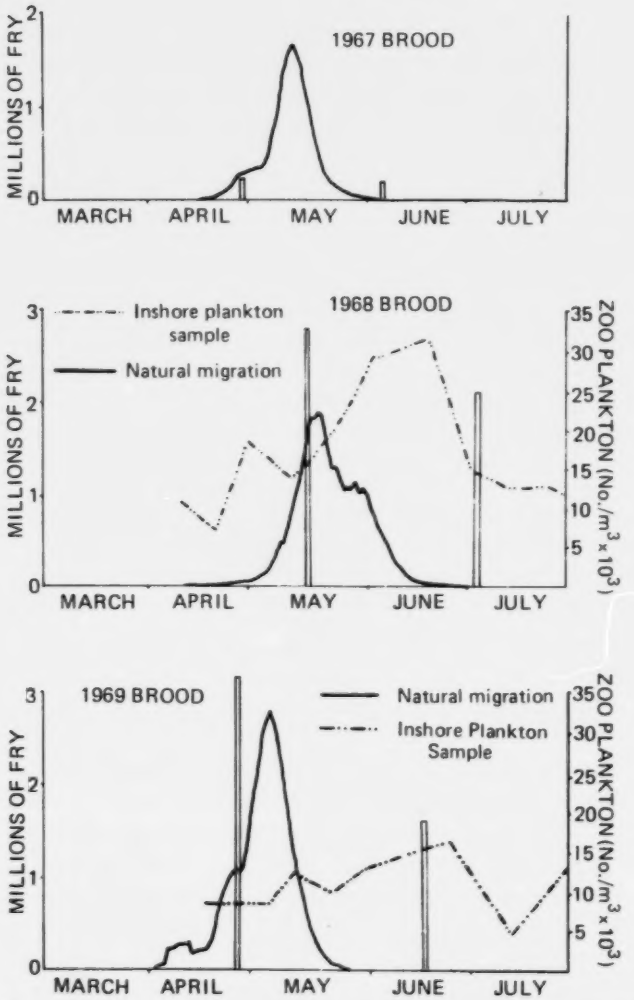


Figure 19. Daily migration of wild chum and mean timing of ponding and release of freshwater reared chum (shown by histogram) (1967 - 69 broods). Graphs for the 1968 and 1969 broods also include plankton abundance data taken during the Big Qualicum marine study in 1969 and 1970 (Fraser et al, 1978a).

taken for rearing are represented by vertical bars. Also included is a graph of zooplankton abundance in the Big Qualicum marine area for the 1968 and 1969 broods. In each year, reared fry were released after the wild migration was over. If, instead, fry for rearing were taken from the earliest part of the run and reared for 30 - 40 days, releases would correspond more closely with the peak migration and increasing plankton abundance.

In Hokkaido, fry are reared for 30 days to 0.8 g and released at a time corresponding to the natural peak migration period (April or May). (T. Kobayashi, unpublished manuscript). Marine survival for the four year period 1965 - 1969 averaged 2.2%. The early fed fry release is possible because incubation and rearing are accelerated through the use of warm groundwater (8°C). The entire process is completed one month earlier than wild development.

Survivals of chum reared at Hoodsport hatchery have also been high in recent years (0.96 - 3.01%) (Mathews and Senn, 1975). Fry are released early (around May 1) at sizes ranging from 1.19 - 1.54 g.

It appears that optimum marine survivals occur when juveniles are released at the time of the peak natural migration but at a larger size than normal migrants. The normal release time ensures that the food supply in the estuary or marine area is optimum and the larger size reduces the susceptability of juveniles to predation.

Routes of Adult Migration

The high ratio of reared-to-unreared chum (5:1) found to migrate through the Strait of Juan de Fuca rather than Johnstone Strait is likely due to the delayed migration of the reared fry. A similar effect has been observed in tag recoveries from early, normal and late releases of 1971 brood coho from Big Qualicum and Rosewall Creek (Argue, 1976). Although analysis of head recovery data is not yet complete, preliminary results show 1.5 to 3 times as many late release coho caught in southern areas as fish released four weeks earlier. Temperature changes and subsequent changes in currents and food distribution during the period of delay are possible causes of the preference for the southern route in late release chum and coho.

Commercial Exploitation, Age Composition and Length of Returning Adults

Freshwater rearing does not appear to have any significant effect on commercial exploitation or age composition of the returning adults. Small sample sizes could account for the minor and inconsistent differences observed.

The smaller size of adipose-anal marked adults could be due to detrimental effects of the mark itself, therefore no responsibility can be attached to the effects of freshwater rearing.

GENERAL RECOMMENDATIONS

The main problem associated with rearing migrant chum juveniles is one of timing. Migrants should be captured as early as possible, fed for about thirty days and released near the end of the downstream migration.

Provided fish are released during May, high temperatures, osmoregulatory stress and related disease problems can be avoided. Loading density and feeding regime can be controlled to produce optimum growth rates and food utilization. If growth rates are limited by low water temperatures, warm groundwater, if available and suitable, may be used as part of the water supply.

The optimum loading density will vary, depending on water temperature and water quality. Based on experience gained at Big Qualicum, it appears that a number of small rearing areas, either separate or partitioned off by screens, would be preferable to one large area. Distributing fry more evenly would lessen localized crowding and feeding competition. Frequent feedings of short duration would also result in more efficient utilization of food.

CONCLUSION

Provided the above recommendations are adhered to, short-term rearing of migrant chum fry could be a viable enhancement technique.

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APPENDIX

Appendix 1. Estimated adult returns of 1967–1969 brood Big Qualicum chum salmon, divided into age categories.

Brood Year	Group	Commercial Catch at Age 3	4	5	Total	Escapement at Age 3	4	5	Total	Total Return at Age 3	4	5	Total
1967	River (AdRV)	4,262	2,571	4,021	10,854	7,784	56,067	2,272	66,123	12,046	58,638	6,293	77,000
	Channel No. 2 (AdLV)	1,261	1,430	1,627	4,318	3,635	23,293	2,836	29,764	4,896	24,723	4,463	34,100
	Reared (Ad)[1]	–	–	–	–	–	–	–	–	–	–	–	–
1968	River (AdLV)	551	86,733	31,081	118,365	10,972	44,201	25,941	81,114	11,523	130,934	57,022	199,000
	Channel No. 2 (AdRV)	357	54,894	18,964	74,215	7,625	18,478	9,966	36,069	7,982	73,372	28,930	110,000
	Reared (AdAn)	0	5,943	787	6,730	329	3,475	446	4,250	329	9,418	1,233	10,980
1969	River (AdLV)	5,478	148,063	1,289	154,830	8,052	92,754	24,485	125,291	13,530	240,817	25,774	280,000
	Channel No. 2 (AdRV)	5,490	77,561	1,033	84,084	1,198	32,603	19,778	53,579	6,688	110,164	20,811	138,000
	Reared (AdAn)	0	11,126	142	11,268	0	1,566	2,223	3,789	0	12,692	2,365	15,100

[1] Insufficient number of fingerlings marked to accurately determine adult returns